ART. II.—*Summary of the Geology of Southern India. By* CAPTAIN NEWBOLD, F.R.S., &c., *Assistant Commissioner for Kurnool.*

[*Concluded from* Vol. ix., p. 42.]

WITH CONCLUDING REMARKS ON THE CLASSIFICATION OF THE STRATIFIED ROCKS OF SOUTHERN INDIA, ACCOMPANIED BY TABLE SHOWING ORDER OF SUPERPOSITION.

PART XI.

AGES OF THE PLUTONIC AND VOLCANIC ROCKS.

MUCH difficulty will always exist in determining the age of granite, since no petrographical distinction, sufficiently decisive to warrant us dividing it into classes, exists. The opinion of some geologists that the ordinary syenite, or, indeed, any other variety of syenite hitherto discovered in Southern India, is more modern than the usual ternary granite of felspar, quartz, and mica, is unsupported by any of the usual proofs required by geologists to establish a fact of this nature; viz., superposition; included fragments of rocks of a determined age; intrusion into other rocks, with or without alteration.

Dr. Christie[1], a distinguished observer in the field of Indian geology, states that "at the falls of Garsipa there is a variety of granite, which differs from the common granite of India. It is not so old a granite as the latter; is composed of small grains of white felspar, quartz, and mica; has, in some instances, a slaty appearance; and is associated with gneiss and hornblende schists." By this passage, mineral character appears to have been the only test to which this rock was put; but why the small-grained granite should be more recent than the other granites of India is not explained.

The granites of India are doubtless of two or more epochs; since we see the usual granite penetrated by granitic dykes, not only of a smaller-grained, but also of a coarser or more porphyritic granite; and nothing is more common than to witness the ordinary granite pass, by insensible gradations, into the fine-grained and porphyritic varieties.

In speaking of granite, I have alluded to the insufficiency of

[1] Madras Journal, Lit. and Sc., October, 1836, p. 457. Extract from the New Edinburgh Phil. Journal.

mineral structure as a test of the age of rocks, and with regard to a highly inclined or vertical stratification being a decisive proof of the antiquity of a formation, and horizontality of a modern origin, it is now ascertained beyond doubt, that secondary and even tertiary beds are found in a vertical position, and the oldest stratified rocks in a state of perfect repose. I have seen the tertiary nummulitic limestones of Egypt bouleversed by granite as well as lias and chalk strata; while, on the other hand, gneiss and the hypogene series are sometimes seen quite horizontal. A great part of Russia, according to Mr. Murchison and M. Verneuil, is covered with the older stratified rocks, extending in horizontal unbroken masses for the distance of nearly one thousand miles.

While it is indisputably certain that the age of different granites cannot be decided by mineral distinctions alone; still, as Mr. Lyell[1] most justly observes, one of these granites is sometimes found exclusively prevailing throughout an extensive region, where it preserves a homogeneous character; so that having ascertained its relative age in one place, we can easily recognize its identity in others, and thus determine, from a single section, the chronological relations of large mountain masses. Having observed, for example, that the syenitic granite of Norway, in which the mineral called zircon abounds, has altered the silurian strata wherever it is in contact, we do not hesitate to refer all masses of the same zircon-syenite in the south of Norway to the same era. The granite of India is not so easily mineralogically distinguished as the zircon granite of Norway, or as the stanniferous granite of the Malay peninsula; still its unusually ferriferous character, its embedding occasionally colophonite and garnet, and generally having hornblende as one of the constituents, will enable the geologist to identify it in various parts of Southern India.

It is chiefly upon the very remarkable distinction of embedding the diamond, in addition to similarity of geognostic position, that we are enabled to identify the diamond sandstones of Kurnool and Cuddapah with those of Nagpoor and Bundlecund; and it is upon these grounds that having seen the syenitic granite of India altering, bouleversing, and forming breccias at the line of junction with this diamond sandstone and limestone, that we come to the conclusion that the newer granite of Southern India is of a more modern epoch than these stratified rocks which rank next in point of antiquity to the hypogene series, while the latter invariably occupy the lowest position in the normal rocks of Southern India.

[1] Elements, Vol. II. p. 351.

Not only is the newer granite of Southern India indubitably of later origin than the diamond sandstone, but there is great reason to believe that its last appearance above the face of the waters was contemporaneous with that of the laterite, as it is evident that the surface of India has undergone several oscillations.

That distinguished geologist, Elie de Beaumont, in the *exposé* of his theory of ascertaining the relative ages of mountain chains by parallelism of elevation, has attributed the elevation of the Western Ghauts to a period subsequent to the deposition of the laterite. This sagacious reasoner has supposed the great dislocation to which the western scarp of this chain is owing, to have been formed at the time of the elevation of this tract above the surface of the ocean, and the laterite to have been deposited previously to, and elevated contemporaneously with, this enormous fault taking place.

It appears to me, after an attentive examination of this great geological feature of India in many situations, both at the base and summit, that several distinct epochs of *soulèvement* must have contributed to produce the present relative positions of the strata. The first—one marked by plutonic energy and violence; the last—long-continued and gentle.

We see the hypogene schists, through which the granite peaks of the Ghauts rise, everywhere in a state of disturbance, bent, contorted, highly inclined, and often in vertical layers on which the laterite reposes in horizontal tabular masses. Had the laterite been deposited on their surface prior to the first violent movement, or series of movements, of which the subjacent granite formed the lever to effect the bouleversement of the hypogene strata, the laterite would have exhibited marks of corresponding disturbance and alteration, which are not evident.

In order to account for the presence of this rock in unconformable and unaltered beds on the vertical subjacent strata, and cresting the granite itself, both at the summit of the Ghauts on the table-lands, and covering the low land at the base of the Ghauts to the sea, it may be inferred that the violent efforts by which the granite was forced through the hypogene strata, and by which it threw them on their edges, took place in the bed of the ocean, or that, after elevation, they again subsided, to undergo a second upheaval.

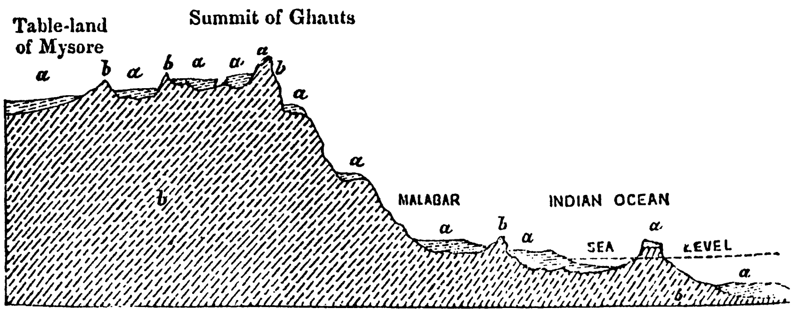
To these violent efforts a period of repose, or comparative repose, ensued; during which, and the subsequent gentler oscillations of the whole mountain mass, and the low coast tracts at its feet, the laterite was deposited; much of it, probably, while the Ghaut peaks were yet islets in the ocean. It is evident from the highly cellular structure of

the laterite, that its formation did not take place under circumstances of great pressure. Its highly ferruginous character, and the embedded fragments of granite, gneiss, trap, &c., occasionally found in its lower portions, sufficiently prove its detrital origin from these ferriferous rocks. Most of the fragments are little water-worn—a fact indicative of the tranquil state of the waters at the time of deposition.

The *débris* of the broken up hypogene strata afforded ample material on the spot; and which, had strong currents existed at the time of their being broken up, would have been scattered far and wide over the ocean's bed; and the result would have been an ordinary sandstone, instead of the peculiarly structured rock we now see.

Whilst this deposit was yet in progress, the Ghauts, and indeed the greatest part of peninsular India, were alternately gradually raised and depressed. The highest and consequently first raised portions became rapidly clothed with forests and luxuriant vegetation, which afforded material for the interstratified beds of lignite we see in the laterite of Malabar and Travancore.

The laterite, though not seen on the steeper portions of the scarp of the Ghauts, is often met with covering the terraces that occasionally break the face of the escarpment, as seen in the subjoined section.



The portions marked *a* denote laterite; *b*, granite and hypogene rocks.

The whole of the granite and hypogene line marked *b* was once, like the portion to the left of the section, the uneven bed of the ocean, on the hollows and inequalities of which the laterite was deposited, as the mass slowly rose to the surface. There is, I think, little reason for supposing that the beds on the summit, and those at the foot of the Ghauts, were once continuous, and afterwards separated by the violent effort that caused the scarp, or dislocation, as thought by some writers. Had such been the case, the laterite would have been broken up, thrown on its edges, and altered like the hypogene schists, as I have

already explained. Its imbedded angular pieces of granite prove that the granite was solid when the laterite was deposited; and its unaltered state, when seen in contact, that the granite has not since been heated.

The horizontal position of laterite, at such heights, sometimes upwards of six thousand feet above the sea, in the bed of which it was formed, is by no means peculiar. The sandstone forming the Table Mountain at the Cape of Good Hope is elevated on granite and hypogene rocks to upwards of three thousand five hundred feet above the sea in perfectly horizontal strata; and in the south of Sicily, and in Greece, I have seen tertiary limestone rocks in equally undisturbed stratification at the height of nearly two thousand feet above the sea.

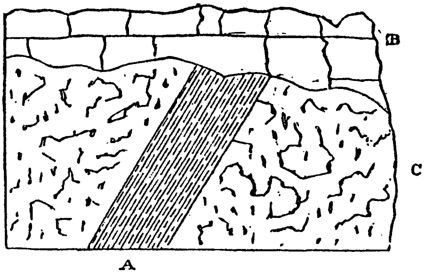
At the time Elie de Beaumont wrote his theoretical opinions regarding the age of the Western Ghauts, that of laterite was wrapped in obscurity; but the discovery in it of beds of lignite and fossil wood, and its superior position to most other stratified rocks of Southern India, claim for it a place in the tertiary series. It seems now conclusive that the great chain of the Western Ghauts was elevated lastly during the tertiary epoch.

The Himalayas, it is inferred, from the presence of the remains of the monkey, and other animals inhabiting warm climates, in the tertiary beds, which partially cover their flanks above the height of perpetual snow, and which now have a polar flora, have been raised at least ten thousand feet since the extinction of these races, within the post-pleiocene period.

If these inferences be legitimate, it would appear that the opinions of Humboldt, and other physical geographers, regarding the age of the Ghauts and Himalayas relatively to those of the other great mountain chains of our planet, must undergo modification.

Age of the Basaltic Greenstone.

The basaltic greenstone, though occupying originally a lower position beneath the earth's crust than the granite, through the vertical fissures of which it has forced itself up, is of course, geologically speaking, posterior to it, though anterior to the overlying trap, which often covers granite and hypogene rocks penetrated by dykes of basaltic greenstone. The dykes terminate at the line of junction abruptly with the granite, without entering into or altering the superincumbent strata of trap or amygdaloid, as seen in the subjoined section.



A Dyke of basaltic greenstone,
B New or overlying trap.
C Granite.

This basaltic greenstone penetrates all the stratified rocks of Southern India up to the laterite, which it has not hitherto been seen to alter or to enter. The dykes are most frequent in the hypogene and granitic rocks, and less so in the upper layers of the diamond sandstone formation, in which period the volcanic activity appears to have greatly subsided.

It is evident that the basalt must have been ejected at more than one epoch, as the dykes are not unfrequently intersected by others of a different texture. Much of it was injected into the granite after the latter had become solid; and into the hypogene schists before they were uplifted and broken up by the elevation and partial protrusion of the plutonic rocks; since the dykes partake of all the displacements of these rocks, and in no case is the basaltic greenstone seen capping them in sheets. These older dykes do not enter into the superincumbent sandstones and limestones; and pebbles of them are occasionally seen in the conglomerates of the former.

Some of the greenstone dykes in the sandsone and limestone appear contemporary with the formation of these stratified rocks, and injected while they existed in a semi-consolidated state, or as layers of mud, gravel, and sand in the ocean's bed; for the greenstone is sometimes curiously and intimately blended with them to a considerable extent, and partakes of their bedded structure, as in the vicinity of Tarputri, Kurnool, &c.

Little mineralogical difference has been remarked, up to the present, in the traps of these two epochs; but the subject is now mooted, I believe, for the first time. I have observed in the dykes of the sandstone and limestone south of Chittywauripilly, in the Ceded Districts, and near the diamond mines of Banganpilly, a reddish foliated mineral, in oval cavities, resembling light red carnelian in appearance and semi-translucency, which has not fallen under my notice in the older dykes. There is also more calc spar (and occasionally selenite) in the former, and a greater tendency to a regular

prismatic and jointed structure. Both these traps resemble, mineralogically, the older traps of Europe, consisting chiefly of basaltic and porphyritic greenstone, rarely running into amygdaloid. I have never seen the older basaltic greenstone of the post-hypogene period become amygdaloidal.

Enough perhaps has been said to justify the division of the basaltic greenstone into at least two epochs, neither of which have been observed to continue into the tertiary period, to which I am about to refer the great Overlying Trap—a rock often confounded with the foregoing.

Age of the Newer or Overlying Trap.

The principal eruption of the newer or overlying trap is referable to an epoch in the tertiary period between the deposition of the freshwater limestones and that of the laterite; for it is seen in the Nirmul hills in the vicinity of Ingliswara, breaking up, altering, and entangling blocks of the former, while the latter rock reposes on it unpenetrated and unaltered, and often imbed fragments of the trap.

The elevation of the trap from the bed of the ocean was contemporaneous with that series of efforts which elevated the granite and laterite of the Western Ghauts. Numerous dykes throughout the great extent of trap show that it also is not the product of one great eruption.

Some geologists have confounded it with the older basaltic greenstone associated with the granite and hypogene rocks of the more southern parts of India. It is, however, not only most strikingly distinguished from this rock in a mineralogical point of view, as will be seen on reference to the descriptions of the two rocks, but it invariably occupies a superior position, whenever seen in contact, as in the last woodcut. Another striking difference may also be noticed,—viz., that of the basaltic greenstone never having been observed to cover the rocks it intersects in sheets; the dykes usually ending abruptly at the surface, without spreading laterally. I have never seen it invading rocks of a more modern origin than the Pondicherry limestone or the diamond sandstone; whereas the overlying trap has broken up, and altered the freshwater tertiary limestones of Nirmul.

It appears clear, from what has been urged above, touching the age of plutonic and volcanic rocks, that at least three great epochs of elevation may be marked in the chronology of Indian rocks, independent of those attending the eruptions of basaltic greenstone in the hypogene and diamond sandstone periods.

The first—anterior to the diamond series, by which the hypogene schists were rendered crystalline, and partially subverted.

The second—posterior, during which a newer granite was erupted through fissures in the older, and which altered and disturbed the diamond series. From the circumstance of the upper sandstone's occasionally resting on the limestone in less disturbed strata, it is inferred that the limestone underwent some degree of dislocation prior to the deposition of the former, and consequently that two movements took place during this epoch. There can be little doubt, from the unaltered yet highly inclined position of some of the beds of the diamond series resting on the granite, that much of the latter was protruded in a solid form. Other beds are seen equally inclined with marked alteration,—a fact significant of a highly heated yet solid state of the granite. Some beds, at short distances from the foci of this second plutonic disturbance, are seen reposing nearly horizontally on the hypogene rock, or older granites, unaltered, evincing an elevation on the solid rock attended with little local violence.

The third movement, or rather series of movements, by which a great part of Southern India was slowly and gently elevated to its present height above the ocean, took place, probably, as described in speaking of the Ghaut elevation, during the tertiary period.

These last elevatory forces are attributable rather to volcanic than plutonic activity, since no granite has been yet observed intruding into, or altering tertiary rocks; and the granites of both the epochs just described have been uplifted by them in a solid form. The phenomena of the third movement are possibly connected with those attending and following the grandest basaltic eruptions in the world, viz., those which produced the overlying trap formation of India. The expansion by heat, and gaseous extrication resulting from so vast a body of molten lava, heaving for vent beneath a ponderous crust of granite, &c., seems adequate to produce such effects. In cooling, the portions of the mass still immediately below this crust would naturally contract, and we should expect to find a corresponding subsidence of surface, unless the spaces, as left vacant, be constantly filled up by the pressure of molten matter from regions still nearer the nucleus of our orb.

The numerous hot springs in and around the basaltic region of India are possibly connected with these phenomena, and a register of their temperature might afford indications of the decrease or increase of the subterranean heat, whether thermal or volcanic. Some indications afforded by the tepid springs of the Kurnool and Banganpilly diamond formation incline one to think that, in that area, a decrease

of heat has taken place; but I do not consider these experiments as at all conclusive (Vide Bengal Journal, 1844, No. 148). A register on the rocks on the coasts is also desirable, to ascertain whether there is any general or local subsidence or elevation of surface now in progress. It is almost needless to add that, during these epochs of plutonic and volcanic activity, the surface of India underwent those oscillations necessary to the formation of its successive aqueous strata, to the consolidation of which the plutonic and volcanic heat mainly contributed. During these oscillations, the denudations, of which I have endeavoured to show proofs, must have occurred.

Concluding Remarks on the Classification of the Stratified Rocks of Southern India.

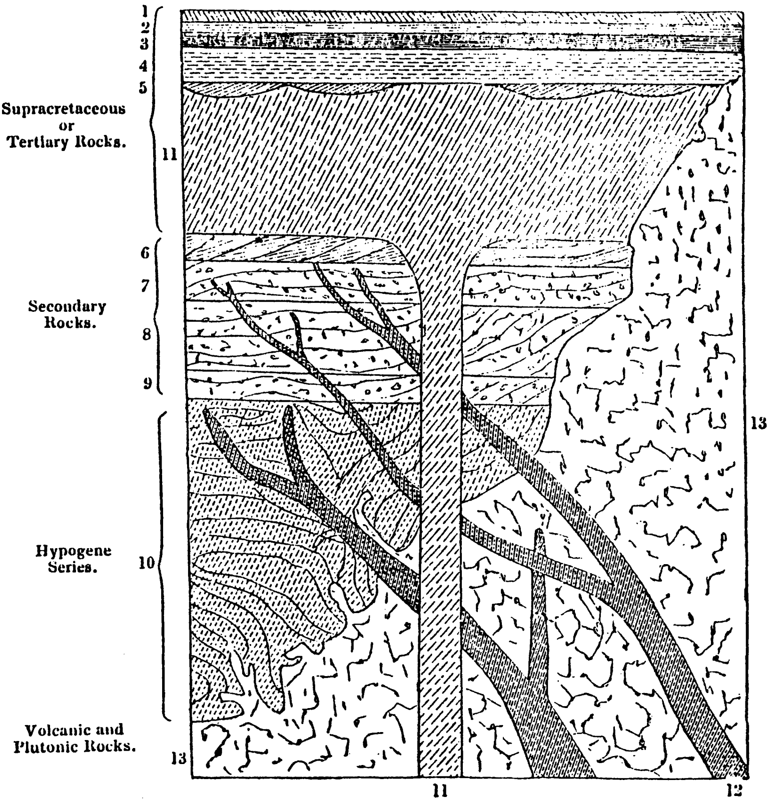
Supracretaceous or Tertiary Rocks.

No. 1. Marine Sandstone of Coromandel.—In the synoptical table of superposition, the marine sandstone of the Coromandel coast overlies the regur, although the former was described, for the sake of convenience, first in the ascending order adopted. It was there stated that these scanty and detached beds, consisting of a loosely agglutinated sandstone, imbedding existing marine shells, were raised to their present position during the same period as the laterite. It must be remarked here that this observation must be understood as applying exclusively to the latest periods of the elevation of the laterite. These marine beds have never been found at any great distance from or elevation above the sea.

Since the paper containing the description of this marine sandstone was sent to England, General Cullen writes me that the beds of it at Cape Comorin form a stratum on the beach some ten or twelve feet thick, resting on granite which occupies the water line, and which extends out to sea in large bare rock masses and islets. Above the sandstone is a hard, close-grained, cream-coloured and reddish limestone, also full of shells, which much resemble those in the sandstone, and those at present thrown up by the sea on the adjacent beach. The limestone can be traced inland perhaps a mile from the sea, and a hundred and fifty feet above it. The Residency stands on a bed of it, about two hundred yards from the sea, and sixty feet above it.

Nos. 2 and 3. Coromandel Black Clay, Regur, Ancient Kunker, and Gravel.—Underneath the alluvial sands and clays on which stand

Synoptical Table of the Rocks of S. India in order of Superposition.



SUPRACRETACEOUS OR TERTIARY STRATA.

1—Sandstone of Coromandel and Paumbum, and Cape Comorin, imbedding existing marine shells.
2—Coromandel Black Clay underlying Madras, &c., and Regur (Pleiocene period).
3—Ancient Kunker, and Gravel imbedding Remains of Mastodon (Pleiocene period).
4—Silicified Wood Deposit of Pondicherry, and older Laterite (Miocene period).
5—Freshwater Limestone of Nirmul, Hydrabad, and Rajahmundry (Eocene period).

SECONDARY STRATA.

6—Limestone beds of Trichinopoly, Verdachillum, and Pondicherry (Neocomien or Lower Chalk).
7, 8, and 9—Diamond Sandstone Group—8 is the Limestone, and 9 the lower Sandstone. (Carboniferous or Devonian.)

10—HYPOGENE SERIES.

Clayslate'
Quartzite
Talcose
Chloritic
Actinolitic
Hornblende
Mica Schists
Gneiss
Protogine
Eurite
Serpentine.

VOLCANIC AND PLUTONIC ROCKS.

11—Newer or Overlying Trap.
12—Basaltic Greenstone.
13—Granite
Syenite
Syenitic Granite
Pegmatite
Porphyritic Granite
Protogine
Eurite
Serpentine
Diallage.

the cities of Madras and Pondicherry, and underlying the recent marine sandstone in many other situations on the coast of Coromandel, is a remarkable bed of a bluish-black clay, which strikingly resembles the regur, if not identical with it, and in which lie entombed the remains of existing marine exuviæ. Below it and the regur we often find a bed of ancient kunker associated with and often agglutinating beds of gravel, in which the remains of the mastodon have been found at Hingoli. While these beds apparently belong to the pleiocene period, the marine sandstone may probably be referred to the post-pleiocene, although at present included among the tertiary strata. The more modern depositions of kunker belong of course to the historical epoch, and occupy no place in the table.

No. 4. Laterite and Silicified Wood Beds.—Next in order come the silicified wood beds of Pondicherry, and the older laterite, which may rank with the lignite and siliceous deposits of the miocene period. The lateritic sandstone imbedding lignite at Beypoor closely resembles the description given[1] of the brown coal formation on the banks of the Rhine, which "consists of loose sand, sandstone, and conglomerate, clay with nodules of clay ironstone, and occasionally silex. Layers of light brown and sometimes black lignite are interstratified with the clays and sands, and often irregularly diffused through them. They contain numerous impressions of leaves and stems of trees."

No. 5. Freshwater Limestones and Cherts of Nirmul and Hydrabad.—These cypriferous beds have been invaded and altered by the newer trap; and, from their imbedding a number of freshwater shells, of the genera physa, paludina, unio, limnea, melania, &c., chiefly of species which no longer exist, may be classed perhaps among eocene strata. Like the eocene freshwater beds of the Cantal, they abound in gyrogonites, and the genera of the prevailing shells assimilate. Both have been invaded and altered by ancient volcanic eruptions, and abound in layers of flint and chert. The Rajahmundry beds near Peddapungoli and Govinpatnam may be referred to the same period.

Before quitting the tertiary beds, it may be briefly mentioned that I have recently discovered, in some caves in the diamond limestone of Kurnool, at Billa Soorgum, on its southern boundary, fragments of bones and tusks, and innumerable bones of bats, &c., fossilized with carbonate of lime, sulphate of lime, and iron, at depths of from eight to twenty feet below the surface, in a bed of reddish marl, indurated

[1] Lyell's Elements, Vol. II. p. 280.

to the hardness of travertin, with nests of crystallized sulphate of lime. The floor of the caves is in general covered by a brown dust, formed by the decomposition of bats' dung, overlying a crust of stalagmite, underneath which lies a bed of mud earth, indurated calcareous clay, and the bone breccia.

Secondary Rocks.

No. 6. *Cretaceous Limestones of Verdachellum, Trichinopoly, and Pondicherry.* The fossils of these beds clearly identify them with the cretaceous system of Europe. Those of Pondicherry appear to rank with the neocomien or lowest beds of the chalk series. Many new forms have been discovered in their fossils, which, it is anticipated, will serve in turn to illustrate and throw new light upon our theories regarding the disputed relations of the cretaceous group with its neighbours.

Nos. 7, 8, *and* 9. *Diamond Sandstone and Limestone Group.*—Although no natural section exhibiting the superposition of the chalk beds has hitherto been discovered, still, for reasons which have been stated in detail, it has been thought advisable to place the diamond sandstone group below them. Since the paper on the latter rocks was sent to England, I have found a second bed of sandstone underlying in conformable stratification the limestone and the sandstone stratum which caps it, a section of which is shown in the next page. The thickness of the beds I ascertained by trigonometrical observations.

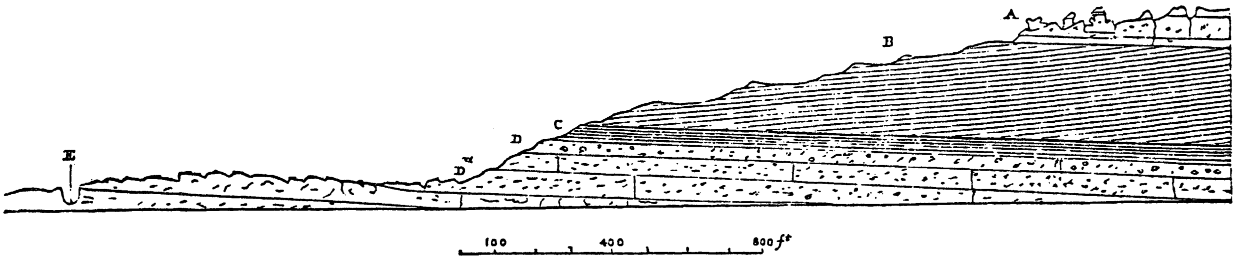
The fissure in the lower sandstone at E, at the bottom of which lie the thermal springs and temple of Moodelaity, presents an imposing feature in the landscape, with its precipices, cliffs, and deep ravines; and in the true scale of height and distance on which the section is drawn, its relative importance is greater than that of the loftiest mountains and deepest theoretical researches of geologists, when compared with the earth's entire bulk. The true amount of dip, ascertained by a clinometer by Chevalier of Paris, is also retained in the section.

The lower bed of sandstone is distinguished from the upper by the absence of the fragments of chert and jasper from the limestone, which abound in the conglomerates of the latter.

The pebbles found in the lower bed are chiefly of white quartz, stained superficially by oxide of iron, which also penetrates into the microscopic chinks by which they are often intersected. A few pebbles of the hardest and toughest portions of the granitic and basaltic greenstone or hypogene rocks on which it rests, viz., quartz, hornstone,

Section of Diamond Sandstone Group.

Pass of Moodelaity, Kurnool, Southern India.



Scale of height and distance in feet.

A—Compact light-coloured sandstone passing into quartz rock and conglomerate—120 feet thick.

B—Beds of limestone compact, of light tints of green, red, and buff, often lined with dark red jasper and light-coloured cherts—thickness 310 feet.

C—Calcareous and argillaceous shales, usually reddish, chocolate, and liver-coloured passing into white; surfaces of laminæ often covered with small light green (chloritic?) flakes.

D—Laminar sandstone; micaceous scales between layers.

Dd—Sandstone, massive.

E—Fissure, at the bottom of which are the temple and thermal springs of Moodelaity.

basalt, and lydian stone, and actinolitic hornblende, are scattered here and there. The softer portions have been ground down into the ordinary mass of sandstone, where they can still be traced in the coarser portions. The iron ore veins in the subjacent rock have yielded the colouring matter.

In the light coloured chert and red jasper veins and beds which intersect the limestone I have recently discovered at Nurnoor and other parts of Kurnool, Cuddapah, and the Hydrabad country, myriads of small subglobose and spheroidal siliceous bodies, often in such numbers as to compose the entire substance of the rock. The sections of these bodies to the naked eye appeared like those of nummulites; but, under a lens, exhibited a decidedly concentric structure, resembling somewhat that of the *Stromatapora concentrica*, a fossil of the limestones of the Eifel and Dudley, figured by Goldfuss, rather than the convolute spiral organization of the nummulite.

In some, the internal structure is very distinct; in others, obliterated more or less, and filled up with the imbedding chert or jasper. Their external spheroidal shape has, in many instances, been flattened, and otherwise altered by pressure.

In weathering, these bodies fall out from their matrix, leaving its surface completely variolated with the innumerable small cavities they occupied, and which bear the impress of their form. They are only discernible in the finer and more siliceous portions of the limestone, though there can be little doubt of their existence in the opaque mass. Doubts are entertained as to their being truly organic; but the great regularity and peculiarity in the structure of these myriads induce me to hesitate, for the present, in classifying them among ordinary concretions or crystalloids.

Christie classed the sandstone with the old red, and the limestone of this group with the hypogene rocks, in the transition series, apparently on the grounds of its supposed mineral resemblance to the transition limestones of Werner, and from its usually inclined stratification in the situations in which he observed it; but I think, from what has before been stated, that we are not warranted as yet in placing it with the sandstones lower than the carboniferous or the Devonian groups.

No. 10. *Hypogene Strata.*—Christie, for the reasons just stated, classed the hypogene strata of the Southern Mahratta country among the transition rocks of Werner. Others (as I did) have called them primitive, from the supposition of their great antiquity, founded upon their non-fossiliferous and highly crystalline character—usually highly inclined strata—and their reposing directly upon granite. Latterly

it has been found that the hypogene strata are rocks of various ages, from the Cambrian to the tertiary, acted upon, rendered crystalline, and mineralogically altered by the effects of plutonic heat; hence the terms of metamorphic, or crystalline, schists often applied to them. All traces of organic bodies in the fossiliferous schists thus metamorphosed are supposed to have been obliterated by the action of the heat, especially in those next the plutonic rocks, or nearest the foci of plutonic intensity. At a distance, the schists become less altered, and gradually re-exhibit their truly fossiliferous character.

I am not aware that undoubted organic bodies have ever been discovered in gneiss, which is usually the lowest rock in the system; but Elie de Beaumont has exhibited to the astonished upholders of the primordial origin of those crystalline rocks, belemnites entombed in micaceous and chloritic schists!

Keilhaus has proved some of the supposed primary crystalline rocks of the north of Europe to be altered fossiliferous strata; while those accomplished geologists, De la Beche, Hoffman, Boué, and others, have demonstrated that the marble of Carrara is nothing but an altered limestone, of the secondary period, belonging to the oolite; and I am inclined to believe, from personal observation, that the celebrated marble of Paros is merely the altered lower or cretaceous limestone of Asia Minor and Mitylene. Hence we may have a secondary and tertiary gneiss, as we have granites of these periods.

But the question here is, whether the hypogene rocks of Southern India are the altered sandstones, limestones, and shales of the diamond group, or those of a more ancient epoch. The circumstance that no fragments of any rocks intervening between it and the granite have been found in the lowest sandstone, added to that of its being the next lowest in succession to the hypogene series, might be considered as arguments in favour of the sandstone groups having been thus metamorphosed; but it may be urged in answer, that an older series of rocks might have been completely metamorphosed before the deposition of the diamond sandstone; in which case nothing beyond their altered fragments would appear in the composition of the sandstone, which is the fact.

The lime which furnished the material for those large sheets of ancient kunker we see deposited over the surface of great part of India by the waters of springs (many of them now thermal) rising up from the bowels of the earth, may have been derived from beds of limestone in these ancient strata while under the action of plutonic heat. Its abstraction may serve to account for, in part, that great deficiency of crystalline limestone, or marble, so remarkable in the

hypogene series of Southern India; and the decrease of the kunker deposit appears to have been contemporaneous with that of plutonic or volcanic activity.

I know not where to look for a remnant of these ancient strata in their unaltered state, save perhaps in the clay slates of the Southern Mahratta country, the relations of which with the diamond sandstone, limestone, and hypogene schist are of considerable intricacy. No fossils have hitherto been found in these rocks.

The whole of the oolite, lias, and Silurian beds appear at present to have no representatives in Southern India, and there is a great deficiency of the carboniferous, Devonian, and other fossiliferous strata. This deficiency, as stated before, while it renders the geology of Southern India uninteresting to the palæontologists of Europe, is in itself a subject for profound research in physical geology.

It is true that Southern India has not yet been fully explored, and that these beds may still be discovered; but sufficient has been elicited to prove *at least* their extreme scantiness relatively to the vast extent over which they are spread, especially the Silurian beds, in Northern Europe. The Silurian strata have been found in North America occupying large areas, in some parts of South America, in the Falkland Islands, and at the Cape of Good Hope; and the gifted founder of this system of rocks is, with reason, sanguine in his anticipations of planting the Silurian standard on the rocks of China, which have already exhibited such magnificent proofs of their carbonaceous treasures on the quays of Nankin.

Like the boulder formation, the older palæozoic strata appear to thin out and diminish as we approach the equator. I have searched in vain for them and boulders on the southern and eastern sides of the Mediterranean, in Egypt, around the shores of the Red Sea, and, nearer the equator on the Malay peninsula.

CONCLUSION.

I have too long trespassed on the patience of the Society to take up much more of its time; but a few words in explanation and apology for the extremely imperfect state in which this Summary of Southern Indian Geology has been offered to its notice, are indispensably necessary in self-defence.

It may be premised, without detriment to their acknowledged talent, that the observations from which it has been compiled, and also

my own, are those of amateurs (with the exception of Voysey), chiefly self-taught employés of Government, with pressing and onerous calls of duty constantly to respond to; next, that the out-door geologist labours under incalculable disadvantages in exploring a tropical country, not only from climate, but from the dense vegetation which clothes its features, and from the few artificial sections, such as mines, quarries, &c., which present themselves in European countries.

The sun's heat admits but of a very few hours' exposure with safety in the early and closing parts of the day: our best and most distinguished geologists—Voysey, Christie, and Benza—have all fallen victims, directly and indirectly, to the effects of climate, in their devotion to geological science; and last, though not least lamented, my excellent friend Malcolmson, who has recently succumbed under a deadly disease, contracted while exploring the geological treasures of the valleys of the Nerbudda and Taptee.

My own notes have been made during a period of sixteen years' service; by the road-side, when marching; or in tracts less frequented, while on sporting excursions, when the hammer, compass, and clinometer accompanied the gun and spear; for I deemed it possible, even for those who run, to snatch a glimpse from nature's book.

The heights laid down in the sections across the peninsula, in absence of a barometer, were taken roughly by the approximative method of the boiling-point; with the exception of a few barometrical measurements obtained from General Cullen's well known table of altitudes, and the height of the Nilgherris, from Dr. Baikie's barometrical observations.

It was intended to have annexed a geological sketch map of Southern India to this Summary; but circumstances have delayed its completion, although the work was far advanced.

The geological notes would have been continued probably some years longer, and offered to the Society in a more ripened and perfect state; but official duties would not admit of their being further pursued. They have been taken as opportunity admitted, and consequently without reference to the general system and method which should be observed in making a comprehensive geological survey of any large tract of country.

With regard to the classification which I have ventured to indicate for Indian rocks, it must be distinctly understood that such arrangement is entirely provisional; and one to which I would fain draw the attention of future and more able observers to rectify, correct, or confirm; for, as yet, I consider we are but on the threshold of Indian geology. The late talented President of the Geological Society, Mr.

Murchison, in his luminous *exposé* of the state and advancement of geological science in various parts of the world embodied in his Anniversary Address for 1843, when speaking of Hindostan, Afghanistan, and China, observed that "Long as Hindostan has been attached to the British Empire, vast lacunæ remain to be filled up before a general geological map of this peninsula can be published; and yet in no part of the earth over which British rule extends is an adequate acquaintance of the subsoil more required. Viewing it as the great centre of civilization of the East, I should hail the day when its Governors, employing competent geologists, shall direct a comprehensive inquiry to be made into the whole of its mineral structure, the results of which must prove to be of the highest national value."

After adverting to Afghanistan, the President turns to China, expressing his confidence that so vast a region may not be laid open to British enterprise without bringing to us some accession of natural knowledge; and after alluding to the coal of Nankin, and the facilities of inland navigation in that part of China, he expresses his opinion, that, by acquiring a thorough acquaintance with the carboniferous sites of China (which is indispensable for a people like ourselves, whose commercial and maritime advancement depends so essentially upon the application of steam power), we shall at the same time obtain a general insight into the physical and geological relations of her rocks. "I would even suggest that agents, possessing sufficient knowledge of coal-fields and mining wealth, should be attached to those permanent stations which are to be occupied by our forces; whence, if a friendly spirit of intercourse is continued, excursions could be made into the interior. Thanks to the diffusion of knowledge, our rulers can now have no difficulty in procuring much useful geological information, even by directing their own officers to make the inquiries within their reach; and if Consuls cannot be found, who, to a familiarity with statistics, add the powers of scientific research, it is at all events well known that our highly instructed corps of Royal" [and I may add H. E. I. C.'s] "Engineers contains within it several good geologists. Let, therefore, British statesmen encourage our science; and, casting their eyes around our vast colonies, apply to them some measure of that geological research which they are so judiciously and liberally patronizing in our own islands."

There is no necessity to call upon the Royal Asiatic Society to echo such enlightened sentiments as these; or upon the Indian Government—the most munificent patrons of science in the world—to back them whenever the time arrives, and fitting opportunity occurs.

For myself,—in bidding farewell to Indian geology, and taking my leave of the Society,—I have to offer it my best thanks for the patience with which it has heard me; feeling assured that it will extend every indulgence to the errors and incapacity of an individual whose labours in the field have been those of pure zeal and love for the science.